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Social and Biological Perspectives to Investigate and Address Illegal Shooting of Raptors

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Social and biological perspectives to investigate and address illegal shooting of raptors

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ABSTRACT

Humans have shot raptors for centuries. However, in many countries these actions have been illegal since the mid-twentieth century. Despite this history, there is not a comprehensive understanding of the characteristics of this activity, its frequency, and why it occurs. We used literature review and principles drawn from ecology, sociology, and criminology to understand this problem. First, we review literature on raptor shooting globally to explore documented motivations for shooting and we describe the history of raptor shooting in the United States of America (USA). Then, to illustrate the contemporary frequency and geographic breadth of the shooting of raptors, we systematically compile records from scientific and media reports from across the USA. Finally, we outline a transdisciplinary framework to meet the challenge of understanding and managing illegal shooting of raptors. Our framework encompasses six best practices: (1) understand the biology of the problem, (2) build professional networks and partnerships, (3) leverage engagement and public support, (4) apply insights from study of human-wildlife interactions, (5) draw lessons from criminology, and (6) use implementation science to evaluate outcomes. We illustrate application of these best practices with a case study from an Illegal Shooting Working Group recently formed in Boise, Idaho, USA. There is growing recognition that illegal shooting of raptors is a pressing conservation challenge. Solving this challenge can be facilitated by inclusion of information from multiple fields of study; the approach we outline provides one potential mechanism to address this issue.

1. Introduction

Human actions affect biodiversity worldwide (Hunter, 2007). Activities tied to consumption or economic development such as overfishing, habitat fragmentation, herbicide use (Hunter, 2007), grazing, and agriculture (Steidl and Powell, 2006) can have widespread negative impacts on wildlife. Additionally, activities tied to recreation such as off-road travel, hiking, cycling, rock climbing, and dog walking also can negatively impact wildlife populations (Steidl and Powell, 2006; Steven et al., 2011; Covy et al., 2019).

In the case of birds, threats from humans are pervasive and diverse (Rosenberg et al., 2019; Canney et al., 2021). For example,

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collisions (e.g., with vehicles, fences, communication towers, energy infrastructure [Loss et al., 2015]), electrocutions (Loss et al., 2014), lead poisoning (Slabe et al., 2022), and pesticide exposure (Russel and Franson, 2014) can all be detrimental to avian populations. Short-term adverse effects of these threats may include changes in behavior of individual animals (Steidl and Powell, 2006) and in energy demands (Bélanger and Bédard, 1990), whereas longer-term adverse effects may include, but are not limited to, shifts in the distribution of at-risk species, reduced reproductive success, endangerment, and extinction (Steven et al., 2011; Garvin et al., 2020; Yang et al., 2021; McClure et al., 2023).

Many species are legally shot as game animals, with management and regulations implemented to promote the long-term viability of their populations. However, illegal shooting of non-game species, including protected species, is a prominent threat of global conservation relevance (Sandor et al., 2017; Katzner et al., 2020). Raptors (birds of prey) in particular are illegally shot with especially high frequency and, because of their demography, this shooting can have relevant impacts for populations (Newton, 2010). Recent work has shown that in the western United States of America (USA), raptors are illegally shot with far greater frequency than was previously recognized. The problem is so pervasive in this region that illegal shooting is a leading cause of death of golden eagles (*Aquila chrysaetos;* Millsap et al., 2022), and, in one recent study, $>$ 65% of birds found dead along power lines were illegally shot (Thomason et al., 2023).

Although there is increasing awareness of the illegal shooting of raptors, there is not a broad-scale understanding of the characteristics of this activity, its frequency, and why it occurs. To understand the ecological and conservation significance of illegal shooting of raptors, we reviewed globally published literature to identify motivations for shooting raptors. Subsequently, we systematically reviewed scientific and media reports to explore the history and geography of raptor shooting within North America. Finally, we developed best practices to understand the complex nature of illegal shooting and to develop appropriate strategies to manage and mitigate this threat.

2. Why are raptors shot?

Historically, governments offered bounties to kill raptors because they were predators or perceived as nuisance species (Pohja-Mykrä et al., 2012; Madden et al., 2019). Today, in many countries, raptors are protected but continue to be shot illegally. There are a number of reasons documented for why people continue to engage in this illegal activity.

A commonly cited motivation for shooting raptors is to protect livestock and domestic animals (Sergio, 2001; Solbakken, 2016; Almuna et al., 2020; Restrepo-Cardona et al., 2020; Salom et al., 2021; Zuluaga et al., 2021). Raptors are predatory and often opportunistic in prey selection. Consequently, they occasionally prey on or scavenge carcasses of animals that humans wish to protect or use. This type of predatory or scavenging behavior may contribute to negative perceptions of raptors. Furthermore, as human livelihoods may depend upon the health and safety of livestock, the welfare of domestic animals may be seen as superseding the welfare of predators or scavengers.

Similarly, people may shoot raptors near fish hatcheries and aquaculture facilities (Monson, 1996; Bechard and Marquez-Reyes, 2003; Restani, 2023). Fish is the main food source for osprey (*Pandion haliaetus*) and fish eagles (e.g., *Haliaeetus* spp., *Icthyophaga* spp). Therefore, facilities that support large concentrations of fish may be especially attractive to these birds (Miron and Chowdhury, 2019; Otiendo, 2019). Communities that rely on fish for sustenance, income, or the management of fish resources, consequently, may deploy tactics, including shooting, to reduce predation at fish hatcheries and aquaculture facilities (Bechard and Marquez-Reyes, 2003; Restani, 2023).

Another common motivation for shooting raptors is a belief that these predators interfere with hunting opportunities for humans (Sergio, 2001; Real et al., 2001; Whitfield et al., 2003; González et al., 2007; Amar et al., 2012). Raptors prey upon small and medium-sized animals, some of which are popular game species for hunters. Consequently, people may shoot raptors to reduce competition for game resources. A relatively high-profile example involves the decades-old and ongoing conflict between raptors and humans on grouse moors in the United Kingdom (UK), where gamekeepers kill large numbers of raptors to protect or enhance game bird populations for hunting purposes (Whitfield et al., 2003; Thirgood and Redpath, 2008).

The global wildlife trade is one of the most prosperous criminal enterprises in the world, and raptors are not exempt from this threat (Kurland and Pires, 2017). The illegal trade of raptors and their derivatives (e.g., heads, feet, feathers) drives persecution in some regions (Buij et al., 2015). For instance, vultures and eagles are sometimes killed so that their feathers and body parts can be used for belief-based purposes, i.e., traditional medicine and cultural rituals (Ogada et al., 2012; Kret et al., 2018; Negro, 2018). In some cases, humans also target birds fitted with transmitters as the electronic devices may be sold and are, therefore, a source of income (Kret et al., 2018).

Although financial motivations may drive the shooting of raptors in some situations, people also shoot raptors for the intangible thrill they obtain from 'killing for sport' (Campbell and Veríssimo, 2015; Sandor et al., 2017; Madden et al., 2019). Killing raptors for sport is documented at migration bottlenecks in Eurasia and on raptor wintering grounds in the Middle East (Raine et al., 2016; Sandor et al., 2017; Rabio and Salama, 2018; Raine et al., 2022). Illegal sport killing of raptors can result in many animals being killed in a short timespan or a relatively narrow geographic region. Some people illegally killing raptors for sport may shoot indiscriminately at any bird crossing their path, while others take a more methodical approach by targeting birds at roost sites (Ellis et al., 1969; Raine et al., 2016). In contrast to the situation that occurs with wildlife trade, the carcasses of birds illegally shot for sport often are left on the landscape without substantial parts or feathers removed.

3. Shooting of raptors in North America-past to the present

As the previous section illustrates, illegal shooting of raptors occurs for a multitude of reasons and in numerous regions of the world. The following review is focused on the history of raptor shooting within North America. We take this approach because the history is unique and there is over a century of documentation describing raptor shooting activities in North America and, specifically, from within the USA.

Throughout the 19th and early 20th centuries, hundreds of thousands of raptors died in North America through government-sanctioned bounties and for sport (Woodgerd, 1952; Madden et al., 2019). To stop this shooting, conservationists in 1938 established one of the world's first non-governmental sanctuaries for birds of prey at Hawk Mountain Sanctuary in Pennsylvania (Goodrich, 1996). Today Hawk Mountain Sanctuary is well known for bird watching and migration counts. However, in the 1920s and 1930s, prior to the establishment of the sanctuary, shooting was one of the most common pastimes at this important raptor migration site. In fact, records indicate that during periods of peak migration, hundreds of raptors were shot daily (Goodrich, 1996).

The actions of Rosalie Edge, who purchased the land for Hawk Mountain Sanctuary, and other conservationists were part of a movement based on an appreciation for birds of prey (Bildstein, 2008). Over time, as awareness grew of the ecological importance of birds and the effects of indiscriminate take on wild bird populations (e.g., passenger pigeon; Schulz et al., 2014), several US states afforded government protections to raptors. Then, in 1940, the USA made an early federal effort to protect raptors, focused on the bald eagle (*Haliaeetus leucocephalus*), by enacting the Bald Eagle Protection Act. This act was amended in 1962 to include golden eagles (*Aquila chrysaetos*) and was renamed the Bald and Golden Eagle Protection Act (BGEPA, 2023). In 1972, all species of raptors received federal protection under an updated Migratory Bird Treaty Act (MBTA, 2023). With these protections and laws in place, shooting any raptor species without a difficult-to-obtain permit became illegal in the USA.

Although nationwide blanket protections for raptors reduced the frequency of large-scale events where multitudes of raptors were killed in a single day, illegal shooting has continued (Bildstein, 2008). For example, records from the period 1975–2014 describing injured birds brought to rehabilitation facilities or the necropsy of dead birds suggest that shooting accounted for 10–25 % of observed raptor mortalities (Fix and Barrows, 1990; Franson and Little, 1996; Russel and Franson, 2014; Hernandez et al., 2018). Similarly, bird banding recovery data also illustrate regular shooting of raptors during the period 1925–2015 (Ritchie and Ambrose, 1995; Hoffman

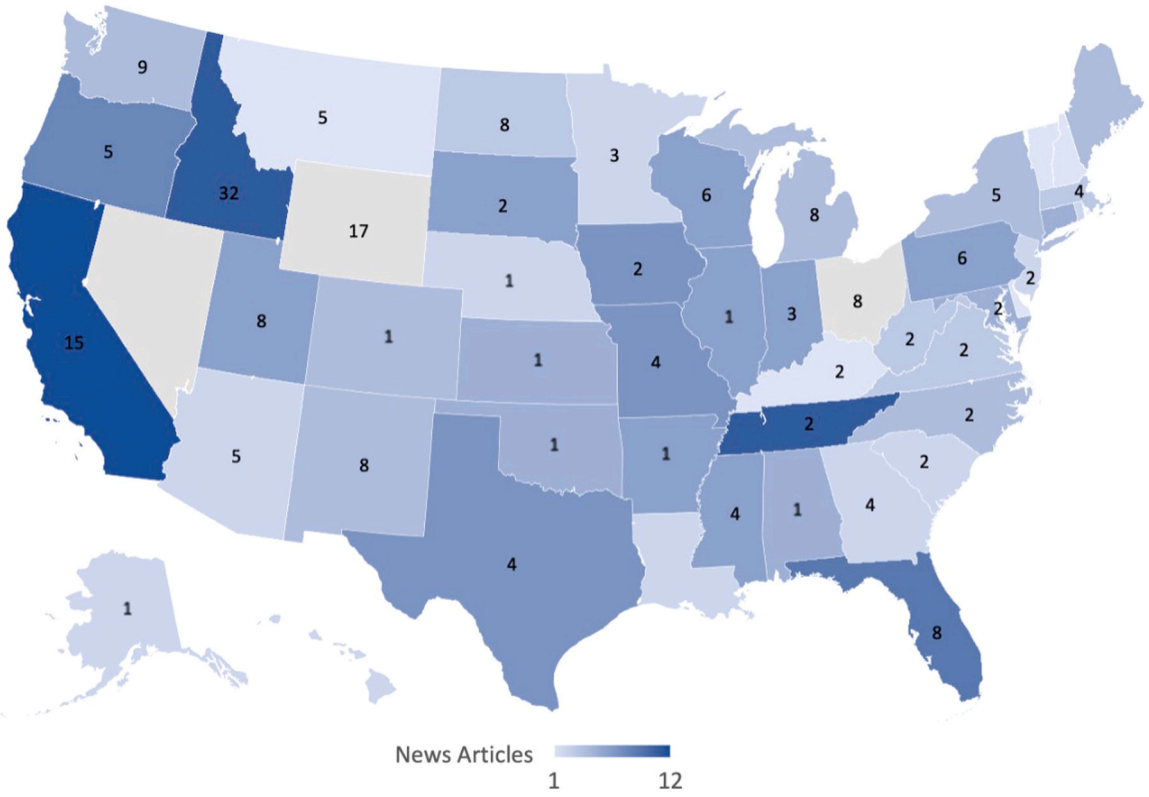

Fig. 1. Map illustrating the geographic distribution of raptor shooting within the USA. Colors indicate number of news articles on raptor shooting in the USA between the years 2000 and 2021 (n = 210). Numbers written within state boundaries indicate the 207 recorded raptor shooting incidents between 2000 and 2021, by state, from records provided by the Teton Raptor Center in Wyoming, the USGS National Wildlife Health Center, and the USGS Bird Banding Lab, and in a scientific publication on causes of death of golden eagles telemetered between 1997 and 2013 (Millsap et al., 2022). States without numbers written within state boundaries indicate zero records of raptor shooting in that particular state.

et al., 2002; Lutmerding et al., 2012; McIntyre, 2012; Morrison and Baird, 2016). Further, recent telemetry studies (Millsap et al., 2022) and surveys along power lines (Katzner et al., 2020; Thomason et al., 2023) indicate that raptor shooting continues today, despite the laws that forbid this activity.

Although evidence suggests many examples of seemingly random events where raptors are shot, there is also evidence of targeted raptor shootings. In the 1960s, a study of the causes of death of 48 raptors along power lines in western Utah suggested that nearly all had been shot (Ellis et al., 1969). Another study of raptor mortality along power lines in Montana found that among raptors with a known cause of death, 84 % died from gunshot (Olson, 1999). More recently, 60–70 % of the raptors found dead along power lines in southwest Idaho had been shot (Katzner et al., 2020; Thomason et al., 2023). Furthermore, Millsap et al. (2022) concluded that shooting was the leading cause of death of golden eagles in the western United States after the eagles reached their first year of life.

Collectively, these studies suggest illegal shooting is more pervasive than generally recognized or documented. Likewise, data also indicate birds are commonly shot along power lines, contradicting a common assumption that most birds found dead along power lines die from electrocution or collision. Raptors may also be more likely to be shot near roads, within conservation areas, and near areas of high human population density (Katzner et al., 2020). Interestingly, some studies point to a possible relationship between illegal shooting of raptors and legal recreational shooting (Ellis et al., 1969; Katzner et al., 2020; Thomason et al. *in review*). Thus, by examining the context of when, where, and how raptors die, researchers can gain insight into the environmental, biological, and social factors involved in the illegal shooting of these protected birds.

4. Contemporary geography of raptor shooting in North America

To provide further insight into raptor shooting in the USA, we systematically reviewed publicly accessible news articles and examined injury and mortality data provided by researchers and wildlife health and rehabilitation centers.

In January 2022, we used the Google Trends (n.d.) online search engine to search for news articles that reported on the shooting of raptors in each of the 50 US states. We conducted 150 separate queries with the search phrases: [“raptor shot *state*”], [“eagle shot *state*”] and [“hawk shot *state*”] (*state* represents the specific name of one of the 50 US states used in the query). We limited our search to the first 10 pages of results and to news articles published between 2000 and 2021. We excluded duplicate records of the same incident (i.e., >1 news outlet reporting the same story). We focused exclusively on raptors shot with firearms and excluded articles that involved raptors shot with other instruments (e.g., arrows, nail guns).

We supplemented our review of news articles with records from a select set of raptor mortality data sources. First, we requested information on the number of shot raptors processed between 2000 and 2021 at The Raptor Center (TRC) in Wyoming and at the US Geological Survey (USGS) National Wildlife Health Center (NWHC) in Wisconsin. Second, we evaluated data from the USGS Bird Banding Lab (BBL) in Maryland for shot birds encountered between 2000 and 2021. Finally, we included data from one scientific publication on causes of death of telemetered golden eagles between 1997 and 2013, which are one of the most commonly shot raptors (Millsap et al., 2022). Because this supplemental dataset was not collected in a standardized manner and also contains geographical biases, we report results from this survey separately from review of news reports.

Our systematic searches identified 210 illegal shooting events covered by news outlets (Fig. 1). These articles documented raptor shootings in 47 states; no articles were retrieved from Nevada, Ohio, or Wyoming. California and Idaho had the highest number of articles reporting the illegal shooting of raptors, with 12 and 11, respectively.

The select set of raptor fatality data provided data on 207 location-specific raptor shooting events. Similar to data from news articles, most states had records of raptor shootings. Idaho, Wyoming, and California had the highest numbers of records, with 32, 17, and 15, respectively.

These supplemental data may be skewed in a number of ways. For example, TRC sits near the border of Idaho and Wyoming, and these states also host many eagles tracked by Millsap et al. (2022). Despite these biases, these data are useful in that they are representative of the best available sources of information on raptor shooting. That said, they are not sufficient to draw other inferences (e.g., rates of shooting), as they are not from standardized studies and are from only a small fraction of the rehabilitation and wildlife health laboratories in the country.

Taken together, these two sources of data provide preliminary information that illustrates that illegal shooting of raptors is a nationwide phenomenon. These data perhaps also indicate regional variation in rates of shooting, public interest, and reporting. For example, our search did not yield any news articles in Wyoming. However, Wyoming had the second-highest number of records in the fatality data. All this information can be useful in developing strategies to address this problem.

5. Addressing the Issue

The history and geographic scope of illegal raptor shooting in the USA demonstrate that this is a significant conservation challenge. Further, the complexity of the problem suggests that a solution will likely require more than a singular perspective or approach (Wickson et al., 2006). In previous work, ecologists often have approached issues of human-raptor interactions, persecution, and coexistence primarily from an ecological perspective—focusing on the effects and proximate causes, rather than ultimate causes such as human behavior and socio-political factors (Canney et al., 2021; but see Thirgood and Redpath, 2008, and associated work, for an exception to this pattern). Raptor conservation in North America has traditionally involved landscape protection and ecological recovery efforts for threatened and endangered species (McClure et al., 2022). Though biological and ecological perspectives are essential facets of raptor conservation, contemporary human-wildlife issues involving raptors in the USA are, in many cases, related less to competition for resources or species scarcity and more to the increasing proximity of, and interactions between, raptors and

humans. As such, there is an opportunity to shift the research and practice landscape toward building transdisciplinary partnerships that facilitate problem-focused and contextualized conservation action (Saunders et al., 2021). In this framing, the word transdisciplinary is used to mean that multiple sectors in and out of traditional scientific research institutions formulate a problem definition and jointly address the problem (Cundill et al., 2015). Thus, a transdisciplinary approach means integrating knowledge and technical approaches from not only biology and ecology, but also from fields such as sociology and criminology that focus on the inherent social elements of this problem.

Here, we propose a transdisciplinary framework based on our media and literature review above and our collective experiences with the widespread conservation challenge of illegal shooting of raptors in the USA. Our approach is based on six steps ("best practices") drawn from multiple disciplines. Finally, we provide a brief case study of implementation of this framework designed to address the illegal shooting of raptors in the "Intermountain West" region of the United States. Presentation of this case study is structured to follow the six steps below, and thus provides an example of how each of these steps may be implemented. Although we do not specifically discuss fund-raising, it should be understood that the framework we propose does rely on financial resources sufficient to achieve these actions.

5.1. *Understand the biology of the problem*

A dearth of biological knowledge on illegal shooting of raptors is a key challenge that researchers and practitioners face to mitigate this activity (Katzner et al., 2020). There are two main unknowns in the realm of ecology: the extent of shooting (e.g., spatial and temporal distribution, species targeted, associated land-use practices) and the relative contribution of shooting to raptor mortality (and, by extension, its demographic relevance). Obtaining reliable information on these unknowns requires field surveys and necropsies that have, in most regions, not been attempted or reported in a consistent or systematic manner. Despite these data gaps, collective efforts by USA-based researchers, managers, and law enforcement officers are beginning to compile information that allows insights into the scope and significance of illegal shooting in specific regions. For instance, research in Idaho suggests that the confluence of power lines, road density, human population centers, and recreational areas may increase the probability of raptor shootings and mortality (Katzner et al., 2020). Further research in the Intermountain West suggests the presence of discrete spatio-temporal patterns—hotspots—of illegal shooting (Thomason et al. *in review*). Collecting sufficient biological and ecological data to uncover potential patterns is an important first step in the process to understand and address the underlying factors contributing to the illegal shooting of raptors.

5.2. *Build professional networks and partnerships*

Focused, collaborative, multi-institutional, and locally-led initiatives are associated with higher probabilities of success when addressing conservation challenges (Brooks et al., 2013; Thomas and Mendezona Allegretti, 2020). Relative to raptor conservation, there is a long history of such collaborative initiatives. These are exemplified by the extensive public-private partnerships that led to the captive breeding and reintroduction programs of peregrine falcons (*Falco peregrinus*; Cade and Enderson, 1988) and California condors (*Gymnogyps californianus*; Snyder and Snyder, 2000). Today, collaborative networks and partnerships remain common in raptor conservation. One example is the partnerships among power utility companies, agencies, and researchers that collectively address electrocutions of birds along power lines (Avian Power Line Interaction Committee; see www.aplic.org, [APLIC, 2006]) and interactions of wildlife and renewable energy facilities (Renewable Energy Wildlife Institute; see www.rewi.org, [REWI, 2023]). Similarly, public-private partnerships and networks of volunteers coordinate hawk migration count sites and data management across North America (e.g., Hawk Migration Association of North America; www.hmana.org, [HMANA, 2023]). Likewise, within the broader avian conservation community, US Fish and Wildlife Service (USFWS) Joint Ventures serve as exemplars in their ability to involve federal, tribal, state, local, corporate, private landowner, and nongovernmental organizations in partnerships to implement bird conservation programs (USJV, 2018). In the case of raptor shooting in the USA, collaborations could include multiple jurisdictions at the state, tribal, and federal levels, and the intersection of management, law enforcement, electricity distribution, and research. Both the literature review (as cited above) and our experience (see Supplemental Materials) suggest that establishing these partnerships is an important step in the path toward addressing the complex challenge of illegal raptor shooting.

5.3. *Build engagement and public support*

Closely related to networks and partnerships is leveraging engagement and support among various publics (McAfee et al., 2020). Wildlife crimes often occur in rural or isolated areas where there are few officers to gain compliance and enforce the law across vast jurisdictions. Consequently, it is rare for officers to witness wildlife crimes. For example, only an estimated 1–5% of incidents of poaching of game animals are brought to the attention of law enforcement (Leavitt et al., 2020). Therefore, engaging hunters, anglers, and other recreationists to report wildlife crimes and to encourage others to adhere to wildlife laws can benefit conservation (Peterson et al., 2019). Raptors, in particular, are charismatic fauna well suited to this type of engagement and public support. For example, the bald eagle is the national bird and symbol of the USA, and at least two states have an official "state raptor"—Idaho designates the peregrine falcon (IDFG, 2004) and Utah the golden eagle (UDWR, 2022). Thus, the symbolism of these species allows them to be leveraged in outreach and engagement, and to build public support, to the extent that a number of global conservation NGOs are focused exclusively on this taxon (e.g., The Peregrine Fund). Leveraging engagement and public support is, therefore, another important step in the process to address the problem of illegal raptor shooting.

5.4. Apply human-wildlife interaction insights and principles

Principles from research on human-wildlife interactions (HWI) can provide insights into the social and cultural landscapes in which conservation challenges occur (Frank, 2014). HWI literature generally indicates that as human populations, habitat encroachment, and development increase, so will the number of interactions between humans and wildlife. Interactions can be positive or negative for both wildlife and humans. For example, habitat improvement projects that promote human well-being and increase available resources for wildlife can be mutually beneficial (Buij and Jacobs, 2020). In contrast, when humans perceive their well-being as threatened (Bessa, 2020) or perceive wildlife species as pests (Frank et al., 2019), outcomes are rarely positive for wildlife.

Sometimes coincident with human-wildlife interactions is human-human conflict (HHC), which can arise when the interests of one party are in opposition to another. Potentially relevant to raptor shooting, cases of HHC tend to involve differences in values, beliefs, and land-use objectives or management goals (Fraser-Celin et al., 2018; Salom et al., 2021). Thus, taking into consideration the priorities and opinions of land users can provide insight into sources of conflict, encourage involvement and open dialogue between affected groups, and improve planning and regulatory processes. Applying considerations from the field of HWI, and understanding HHC, therefore, can improve the success of conservation actions (Fraser-Celin et al., 2018), such as those that may be proposed to address illegal shooting of raptors.

5.5. Apply criminology and legal perspectives

Criminology and perspectives from legal scholarship may help researchers, managers, and law enforcement officers better understand the "why" behind illegal raptor shooting. Criminologists study crime and deviant behavior from social and behavioral perspectives (Sutherland et al., 1992), investigating motivations and rationalizations, deterrence methods, and reactions to sentencing (Wilson and Boratto, 2020). Particularly relevant to conservation challenges, neutralization theory suggests that offenders tend to rationalize exceptions to the rule of law via denials of their own responsibility, of the necessity of the law, or of the victim (Sykes and Matza, 1957). Other common rationalizations include condemnation of condemners (e.g., blaming government or law enforcement for a perceived situation), entitlement, or claims that "everyone is doing it" (Coleman, 1994). While commonplace in investigations of crimes committed against humans, principles of criminology are underutilized in conservation and wildlife crime (Kurland and Pires, 2017; Wilson and Boratto, 2020). The initial review in our manuscript suggests that, aside from the removal of government-sanctioned bounties and despite the promulgation of laws forbidding the activity, the general motivations to shoot raptors have not changed over the last century. Thus, similar to the application of HWI principles and insights, criminology and legal perspectives can assist in understanding context-specific motivations that, in turn, could inform effective enforcement and management decisions (Eliason, 2003) to address illegal shooting of raptors.

5.6. Apply implementation science insights and principles

The effectiveness of conservation actions is rarely assessed, and the failure to assess effectiveness can negatively impact implementation and outcomes (Santika et al., 2022). Moreover, conservation can stall when implementation strategies are inappropriate for or incongruent with the conservation context (Porzecanski et al., 2022). In contrast, effective assessment can orient implementation strategies appropriately to the conservation context (e.g., "what works, when, and why"). Assessment can be achieved using insights and principles from implementation science to help programs monitor, evaluate, adapt, and refine conservation and management actions. Implementation science is the study of strategies and methods to promote the systematic adoption and integration of research findings and evidence-based practices into routine use (Lobb and Colditz, 2013). Implementation science considers multiple scales and measures of success and provides information well suited to adaptively modify intervention methods and management strategies (Michie et al., 2011; Albers et al., 2020; Ferreira and Klütsch, 2021). In the case of illegal raptor shooting, assessment of effectiveness and outcomes of mitigation and management strategies is uncommon. Consequently, it is challenging to identify successful strategies that reduce the frequency of illegal shooting or change underlying sociocultural beliefs related to raptors. Despite relatively high-profile legal cases (CDFW, 2019; DOJ, 2022), illegal shooting of raptors is challenging to observe and report, and prosecutions are rare. However, evidence suggests that reliance solely on law enforcement to manage wildlife crime is an ineffective long-term strategy (Leavitt et al., 2020). Thus, effectively addressing the problem of raptor shooting, whether it be through educating the public, law enforcement response, or management, could be improved via the use of implementation science to monitor, evaluate, adapt, and refine intervention strategies.

5.7. Case study

To illustrate a real-world application of the proposed research framework to address raptor shooting, and to provide examples specific to each of the sections above, we describe a transdisciplinary collaboration, the "Illegal Shooting Working Group" (ISWG, Supplemental Material "Case Study"), which has been developed in Idaho, USA. ISWG activities initially began with field studies that documented the biology of the problem. Once the basic components of the problem were understood, stakeholders began building professional networks and partnerships and engaging and building public support to address the problem. These actions are still ongoing today. Simultaneously, study of this problem has progressed to the point where social scientists have been recruited to help apply principles from HWI and criminology, and to develop effective implementation science to monitor outcomes and improve mitigative actions.

The members of ISWG acknowledge the complexity and context-specific nature of raptor shooting while also recognizing that the challenge cannot be solved by scientists, law enforcement, or resource agency managers alone. Furthermore, although the focus of the group is on a single wildlife conservation problem, the issues faced may mirror those faced by other conservation practitioners and researchers who deal with data deficiencies and discordant prioritizations and efforts among multiple actors. The detailed description we provide in the Supplemental Materials illustrates some of the nuances involved in the six steps we took towards addressing this complex conservation problem and may provide insight for others charting their own courses to address this or other similar implementation challenges.

6. Conclusion

Illegal shooting of raptors is a global conservation concern, and recent studies suggest that the activity may be more common than previously thought. Despite a long history of shooting in North America, knowledge gaps persist in our understanding of the issue and its demographic relevance to wildlife. Furthermore, data deficiencies and discordant prioritizations can hinder enforcement and management efforts, and the effectiveness of short- and long-term management strategies to address this problem is relatively unknown.

There is a path forward for addressing this conservation issue. Because of increased concern about the negative impacts of illegal shooting, there is substantial interest among local, state, and federal agencies to build upon partnerships and address this threat collaboratively. Moreover, efforts are underway to prioritize this issue within management agencies and to acquire funding to conduct much-needed targeted research. Additionally, partnerships with industry have increased access to study sites and raptor carcasses, and collaboration with state wildlife health laboratories or veterinary facilities has increased the frequency of necropsies and assessment of causes of death of birds.

This report is among the first to shed light on the complexity of the ecological, geographical, and sociological components of illegal shooting of raptors. The best practices we have highlighted may serve as a starting point to aid research, planning, and conservation efforts to address illegal shooting in North America. As human activities increasingly threaten raptor populations globally, addressing the long-standing practice of shooting raptors is an important step in the process of conserving biodiversity and reducing human-caused mortality of wildlife.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

Some data included in this manuscript are sensitive and thus, will be made publicly available as law enforcement allow.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gecco.2023.e02631.

References

Albers, B., Shlonsky, A., Mildon, R., 2020. Implementation science, 3.0. Springer.
Almuna, R., Cruz, J.M., Vargas, F.H., Ibarra, J.T., 2020. Landscapes of coexistence: generating predictive risk models to mitigate human-raptor conflicts in forest socio-ecosystems. Biol. Conserv. 251, 108795.
Amar, A., Court, I.R., Davison, M., Downing, S., Grimshaw, T., Pickford, T., Raw, D., 2012. Linking nest histories, remotely sensed land use data and wildlife crime records to explore the impact of grouse moor management on peregrine falcon populations. Biol. Conserv. 145, 86–94.
APLIC. (2006). Suggested practices for avian protection on power lines: The state of the art in 2006. Edison Electric Institute, APLIC, and the California Energy Commission. Washington, D.C. and Sacramento, CA.
Bechard, M.J., Marquez-Reyes, C., 2003. Mortality of wintering ospreys and other birds at aquaculture facilities in Colombia. J. Raptor Res. 37, 292–298.
Bélanger, L., Bédard, J., 1990. Energetic cost of man-induced disturbance to staging snow geese. J. Wildl. Manag. 54, 36–41.
Bessa, E., 2020. Human-wildlife interactions: turning conflict into coexistence. Q. Rev. Biol. 95, 166.
BGEPA. 16 U.S.C. 668–668d.

Bildstein, K.L., 2008. A brief history of raptor conservation in North America. In: Bildstein, K.L., Smith, J., Ruelas, E. (Eds.), The state of North America's birds of prey. Hawk Mountain Sanctuary, Orwigsburg, PA.
Brooks, J., Waylen, K.A., Mulder, M.B., 2013. Assessing community-based conservation projects: a systematic review and multilevel analysis of attitudinal, behavioral, ecological, and economic outcomes. Environ. Evid. 2, 1–34.
Buij, A., Jacobs, M., 2020. Avoiding negativity bias: towards a positive psychology of human-wildlife relationships. R. Swed. Acad. Sci. 50, 281–288.
Buij, R., Nikolaus, G., Whytock, R., Ingram, D.J., Ogada, D., 2015. Trade of threatened vultures and other raptors for fetish and bushmeat in West and Central Africa. Oryx 50, 606–616.
Cade, T.J., Enderson, J.H., 1988. Peregrine falcon populations: their management and recovery. The Peregrine Fund.
Campbell, B., Veríssimo, D., 2015. Black stork down: military discourses in bird conservation in Malta. Hum. Ecol. 43, 79–92.
Canney, A.C., McGough, L.M., Bickford, N.A., Wallen, K.E., 2021. Systematic map of human–raptor interaction and coexistence research. Animals 12, 45.
CDFW) (2019). Lassen County raptor poacher convicted. Published April 12, 2019. ⟨https://cdfgnews.wordpress.com/2019/04/12/lassen-county-raptor-poacher-convicted/⟩.
Coleman, J.W., 1994. The Criminal Elite: The Sociology of White-collar Crime. St. Martin's Press, New York.
Covy, N., Benedict, L., Keeley, W.H., 2019. Rock climbing activity and physical habitat attributes impact avian community diversity in cliff environments. Jan 16 PLoS One 14 (1), e0209557. https://doi.org/10.1371/journal.pone.0209557.
Cundill, G., Roux, D.J., Parker, J.N., 2015. Nurturing communities of practice for transdisciplinary research. Ecol. Soc. 20, 22.
DOJ) (2022). Two men sentenced for the unlawful taking of a golden eagle. Published June 15, 2022. ⟨https://www.justice.gov/usao-id/pr/two-men-sentenced-unlawful-taking-golden-eagle⟩.
Eliason, S.L., 2003. Illegal hunting and angling: the neutralization of wildlife law violations. Soc. Anim. 11, 225–243.
Ellis, D.H., Smith, D.G., Murphy, J.R., 1969. Studies on raptor mortality in western Utah. Gt. Basin Nat. 29, 165–167.
Ferreira, C.C., Klütsch, C.F.C. (Eds.), 2021. Closing the knowledge-implementation gap in conservation science. Springer.
Fix, A.S., Barrows, S.Z., 1990. Raptors rehabilitated in Iowa During 1986 and 1987: a retroactive study. J. Wildl. Dis. 26, 18–21.
Frank, B., 2014. Human-wildlife conflicts and the need to include tolerance and coexistence: an introductory comment. J. Soc. Nat. Resour. 29, 738–743.
Frank, B., Glikman, J.A., Marchini, S. (Eds.), 2019. Human–wildlife Interactions: Turning Conflict Into Coexistence, 23. Cambridge University Press.
Franson, J.C., Little, S.E., 1996. Diagnostic findings in 132 great horned owls. J. Raptor Res. 30, 1–6.
Fraser-Celin, V., Hovorka, A.J., Silver, J.J., 2018. Human conflict over wildlife: exploring social constructions of African wild dogs (*Lycaon pictus)* in Botswana. Hum. Dimens. Wildl. 23, 341–358.
Garvin, J.C., Slabe, V.A., Cuadros Díaz, S.F., 2020. Conservation Letter: Lead poisoning of raptors. J. Raptor Res. 54, 473-470.
González, L.M., Margalida, A., Mañosa, S., Sánchez, R., Oria, J., Molina, J.I., Caldera, J., Aranda, A., Prada, L., 2007. Causes and spatio-temporal variations of non-natural mortality in the vulnerable Spanish imperial eagle Aquila adalberti during a recovery period. Oryx 41, 495–502.
Goodrich, L., 1996. The place where hawk watching was born. Nat. Hist. 105, 48.
Google Trends (n.d.). raptor shot *state*, eagle shot *state* and hawk shot *state*. Retrieved January 2022, from ⟨https://trends.google.com/home⟩.
Hernandez, C.L., Oster, S.C., Newbrey, J.L., 2018. Retrospective study of raptors treated at the Southeastern Raptor Center in Auburn, Alabama. J. Raptor Res. 52, 379–388.
HMANA) (2023). Hawk migration studies. HMANA, 49:1–44.
Hoffman, S.W., Smith, J.P., Meehan, T.D., 2002. Breeding grounds, winter ranges, and migratory routes of raptors in the Mountain West. J. Raptor Res. 36, 97–110.
Hunter, P., 2007. The human impact on biological diversity: How species adapt to urban challenges sheds light on evolution and provides clues about conservation. EMBO Rep. 8, 316–318.
IDFG) (2004). Wildlife Express. Volume 18, Issue 1, Published September 2004. ⟨https://idfg.idaho.gov/old-web/docs/wildlifeExpress/2004sep.pdf⟩.
Katzner, T.E., Carlisle, J.D., Poessel, S.A., Thomason, E.C., Pauli, B.P., Pilliod, D.S., Belthoff, J.R., Heath, J.A., Parker, K.J., Warner, K.S., Hayes, H.M., Aberg, M.C., Ortiz, P.A., Amdor, S.M., Alsup, S.E., Coates, S.E., Miller, T.A., Duran, Z.K., 2020. Illegal killing of Nnngame wildlife and recreational shooting in conservation areas. Conserv. Sci. Pract. 2.
Kret, E., Rabeil, T., Muhammad, S.I., Shiiwua, M., Hall, P., Arkumarev, V., Dobrev, V., Nikolov, S.C., 2018. First documented case of the killing of an Egyptian vulture (*Neophron percnopterus)* for belief-based practices in western Africa. Vie Milieu 7.
Kurland, J., Pires, S.F., 2017. Assessing USA wildlife trafficking patterns: how criminology and conservation science can guide strategies to reduce the illegal wildlife trade. Deviant Behav. 38, 375–391.
Leavitt, K., Wodahl, E.J., Schweitzer, K., 2020. Citizen willingness to report wildlife crime. Deviant Behav. 42, 1256–1272.
Lobb, R., Colditz, G.A., 2013. Implementation science and its application to population health. Annu. Rev. Public Health 34, 235–251.
Loss, S.R., Will, T., Marra, P., 2014. Refining estimates of bird collision and electrocution mortality at power lines in the United States. PloS One 9, 101565.
Loss, S.R., Will, T., Marra, P., 2015. Direct mortality of birds from anthropogenic causes. Annu. Rev. Ecol. Evol. Syst. 46, 99–120.
Lutmerding, J.A., Rogosky, M., Peterjohn, B., McNicoll, J., Bystrak, D., 2012. Summary of raptor encounter records at the Bird Banding Lab. J. Raptor Res. 46, 17–26.
Madden, K.K., Rozhon, G.C., Dwyer, J.F., 2019. Conservation letter: Raptor persecution. J. Raptor Res. 53, 230–233.
MBTA). 16 U.S.C. 703–712.
McAfee, D., Reinhold, S., Alleway, H.K., Connell, S.D., 2020. Environmental solutions fast-tracked: reversing public skepticism to public engagement. Biol. Conserv. 253, 108899.
McClure, C.J., Dunn, L., Buechley, E.R., Juergens, P., Oleyar, D., Goodrich, L.J., Therrien, J.F., 2022. Conservation assessment of raptors within the USA and Canada. Biol. Conserv. 272, 109633.
McClure, C.J.W., Vargas, F.H., Amar, A., Concepcion, C.B., MacColl, C., Sumasgutner, P., 2023. Conservation Letter: monitoring raptor populations – a call for increased global collaboration and survey standardization. J. Raptor Res. 57, 106–113.
McIntyre, C.L., 2012. Quantifying sources of mortality and wintering ranges of golden eagles from interior Alaska using banding and satellite tracking. J. Raptor Res. 46, 129–134.
Michie, S., van Stralen, M.M., West, R., 2011. The behaviour change wheel: A new method for characterizing and designing behaviour change interventions. Implement. Sci. 6, 42.
Millsap, B.A., Zimmerman, G.S., Kendall, W.L., Barnes, J.G., Braham, M.A., Bedrosian, B.E., Bell, D.A., Bloom, P.H., Crandall, R.H., Domenech, R., Driscoll, D., 2022. Age-specific survival rates, causes of death, and allowable take of golden eagles in the western United States. Ecol. Appl. 32, 2544.
Miron, M.K., Chowdhury, S.U., 2019. Breeding density and habitat selection of the grey-headed fish-eagle in Noakhali District, Bangladesh. J. Raptor Res. 53, 134–141.
Monson, C.S., 1996. Geographical review of the historical and current status of ospreys *(Pandion haliaetus)* in Utah. Gt. Basin Nat. 56, 150–156.
Morrison, J.L., Baird, J.M., 2016. Using banding and encounter data to investigate movements of red-tailed hawks in the northeastern United States. J. Raptor Res. 50, 161–175.
Negro, J.J., 2018. Raptors and people: aan ancient relationship persisting today. Birds of Prey. Springer, Cham, pp. 161–176.
Newton, I. (2010). Population ecology of raptors. A&C Black.
Ogada, D.L., Keesing, F., Virani, M.Z., 2012. Dropping dead: causes and consequences of vulture population declines worldwide: worldwide decline of vultures. Ann. N. Y. Acad. Sci. 1249, 57–71.
Olson, C. (1999). Human-related causes of raptor mortality in western Montana: Things are not always as they seem. In: Carlton, R. L. (Ed.), Avian interactions with utility and communication structures. Concord, CA: EPRI Technical Report, pp.85–103.
Otiendo, N.E., 2019. Economic impact of predatory piscivorous birds on small-scale aquaculture farms in Kenya. In: Aquaculture Rep., 15.
Peterson, M.N., Von Essen, E., Hansen, H.P., Peterson, T.R., 2019. Shoot shovel and sanction yourself: self-policing as a response to wolf poaching among Swedish hunters. Ambio 48, 230–239.

Pohja-Mykrä, M., Vuorisalo, T., Mykrä, S., 2012. Organized persecution of birds of prey in Finland: historical and population biological perspectives. Ornis Fenn. 89, 1.
Porzecanski, A.L., Sterling, E.J., Copsey, J.A., Appleton, M.R., Barborak, J.R., Bruyere, B.L., Valdés-Velásquez, A., 2022. A systems framework for planning and evaluating capacity development in conservation: recommendations for practitioners. Oryx 1–10.
Rabio, B., Salama, W., 2018. Hunting and trapping practices in Egypt's northern Mediterranean Coast. Nat. Conserv. Egypt 64.
Raine, A.F., Gauci, M., Barbara, N., 2016. Illegal bird hunting in the Maltese Islands: an international perspective. Oryx 50, 597–605.
Raine, A.F., Hirschfeld, A., Attard, G.M., Scott, L., Ramadan-Jaradi, G., Serhal, A., Driskill, S., 2022. The international dimension of illegal bird hunting in Lebanon. Sandgrouse 43, 230–240.
Real, J., Grande, J.M., Mañosa, S., Sánchez-Zapata, J.A., 2001. Causes of death in different areas for Bonelli's eagle *Hieraaetus Fasciatus* in Spain. Bird. Study 48, 221–228.
Restani, M., 2023. Range contraction of an Osprey population following lethal control at a state fish hatchery in Montana. Journa Raptor Res. 57, 69–74.
Restrepo-Cardona, J.S., Echeverry-Galvis, M.A., Maya, D.L., Vargas, F.H., Tapasco, O., Renjifo, L.M., 2020. Human-raptor conflict in rural settlements of Colombia. Edited by Bi-Song Yue. PLOS One 15, e0227704.
REWI). (2023). National Wind Wildlife Research Plan 2020–2023. Washington, DC. Available at www.awwi.org.
Ritchie, R.J., Ambrose, S., 1995. Distribution and population status of bald eagles *(Haliaeetus leucocephalus)* in interior Alaska. Arctic 49, 120–128.
Rosenberg, K.V., Dokter, A.M., Blancher, P.J., Sauer, J.R., Smith, A.C., Smith, P.A., et al., 2019. Decline of the North American avifauna. Science 366, 120–124.
Russel, R.E., Franson, J.C., 2014. Causes of mortality in eagles submitted to the National Wildlife Health Center 1975-2013. Wildl. Soc. Bull. 38, 697–704.
Salom, A., Suárez, M.E., Destefano, C.A., Cereghetti, J., Vargas, F.H., Grande, J.M., 2021. Human-wildlife conflicts in the southern Yungas: what role do raptors play for local settlers? Animals 11, 1428.
Sandor, A., Jansen, J., and Vansteelant, W.M. (2017). Understanding hunters' habits and motivations for shooting raptors in the Batumi raptor-migration bottleneck, Southwest Georgia. Sandgrouse, 39:15.
Santika, T., Sherman, J., Voigt, M., Ancrenaz, M., Wich, S.A., Wilson, K.A., Possingham, H., Massingham, E., Seaman, D.J., Ashbury, A.M., Azvi, T.S., 2022. Effectiveness of 20 years of conversation investments in protecting orangutans. Curr. Biol. 32, 1754.
Saunders, S.P., Wu, J.X., Gow, E.A., Adams, E., Bateman, B.L., Bayard, T., Beilke, S., Dayer, A., Fournier, A., Fox, K., Heglund, P., Lerman, S., Michel, N., Paxton, E., Sekercioglu, C., Smith, M., Thogmartin, W., Woodrey, M., van Riper, C., 2021. Bridging the research-implementation gap in avian conservation with translational ecology. Ornithol. Appl. 123, 1–13.
Schulz, J.H., Otis, D.L., Temple, S.A., 2014. 100th anniversary of the passenger pigeon extinction: lessons for a complex and uncertain future. Wildl. Soc. Bull. 38, 445–450.
Sergio, F., 2001. Density, productivity, diet, and human persecution of golden eagles (*Aquila chrysaetos)*. J. Raptor Res. 35, 40–48.
Slabe, V.A., Anderson, J.T., Millsap, B.A., Cooper, J.L., Harmata, A.R., Restani, M., Crandall, R.H., Bodenstein, B., Bloom, P.H., Booms, T., Buchweitz, J., Culver, R., Dickerson, K., Domenech, R., Dominguez-Villegas, E., Driscoll, D., Smith, B.W., Lockhart, M.J., McRuer, D., Miller, T.A., Ortiz, P.A., Rogers, K., Schwarz, M., Turley, N., Woodbridge, B., Finkelstein, M.E., Triana, C.A., DeSorbo, C.R., Katzner, T.E., 2022. Demographic implications of lead poisoning for eagles across North America. Science 375, 779–782.
Snyder, N.F.R., Snyder, H., 2000. The California Condor: a Saga Of Natural History and Conservation. Princeton University Press.
Solbakken, K. (2016). Killing of golden eagles adopted by the Norwegian parliament. Birdlife Norway. ⟨https://www.birdlife.no/internasjonalt/nyheter/?id=1713⟩.
Steidl, R.J., Powell, B.F., 2006. Assessing the effects of human activities on wildlife. Georg. Wright Forum 23, 50–58.
Steven, R., Pickering, C., and Castley, J.G. (2011). A review of the impacts of nature-based.
Sutherland, E.H., Cressey, D.R., Luckenbill, D.F., 1992. Principles of Criminology. Altamira Press.
Sykes, G., Matza, D., 1957. Techniques of neutralization: a theory of delinquency. Am. Sociol. Rev. 22, 664–670.
Thirgood, S., Redpath, S., 2008. Hen harriers and red grouse: science, politics and human-wildlife conflict. J. Appl. Ecol. 45, 1550–1554.
Thomas, R.E., Mendezona Allegretti, A., 2020. Evaluating the process and outcomes of collaborative conservation: tools, techniques, and strategies. Soc. Nat. Resour. 33, 433–441.
Thomason, E.C., Turley, N.J.S., Belthoff, J., Katner, T., 2023. Illegal shooting is now a leading cause of death of birds along power lines in the western USA. iScience. https://doi.org/10.1016/j.isci.2023.107274.
UDWR) (2022). Golden eagle named Utah's state bird of prey. Published 25 March 2022. ⟨https://wildlife.utah.gov/news/utah-wildlife-news/1387-golden-eagle-named-utah-state-bird-of-prey.html⟩.
United States Joint Ventures (USJV) (2018). North American Waterfowl Management Plan Update. CW66-393/2018E-PDF.
Whitfield, D.P., McLeod, D., Watson, J., Fielding, A.H., Haworth, P.F., 2003. The Association of grouse moor in Scotland with the illegal use of poisons to control predators. Biol. Conserv. 114, 157–163.
Wickson, F., Carew, A.L., Russell, A.W., 2006. Transdisciplinary research: characteristics, quandaries and quality. Futures 38, 1046–1059.
Wilson, L., Boratto, R., 2020. Conservation, wildlife crime, and tough-on-crime policies: lessons from the criminological literature. Biol. Conserv. 251, 108810.
Woodgerd, W., 1952. Food habits of the golden eagle. J. Wildl. Manag. 16, 457.
Yang, X., Shicheng, L., Hughes, A., Feng, G., 2021. Threatened bird species are concentrated in regions with less historical human impacts. Biol. Conserv. 255.
Zuluaga, S., Hernán Vargas, F., Grande, J.M., 2021. Integrating socio-ecological information to address human–top predator conflicts: the case of an endangered eagle in the eastern Andes of Colombia. Perspect. Ecol. Conserv. 19, 98–107.